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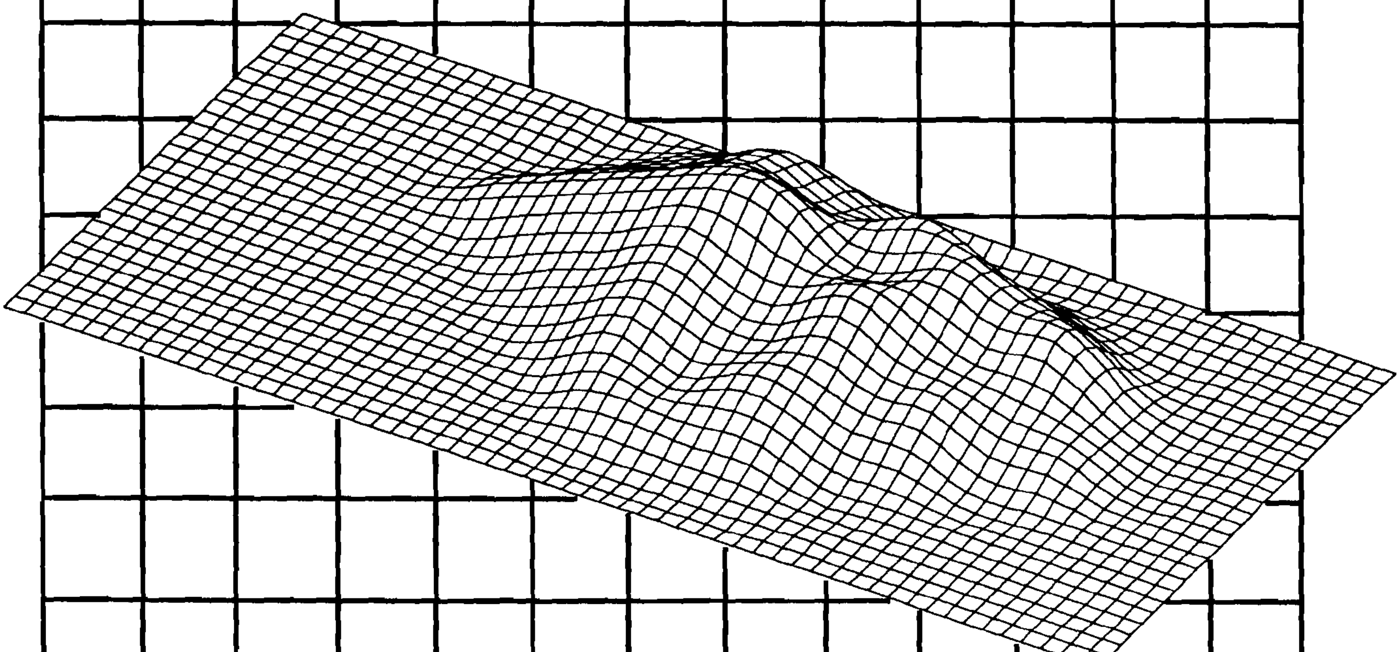
Grid Soil Sampling and Fertilization



THE OHIO STATE UNIVERSITY EXTENSION

Grid Soil Sampling and Fertilization

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The soil concentration of individual plant nutrients varies from field to field and within fields. The minimum concentration of each nutrient needed for optimum plant growth varies by both crop and yield goal. Farmers routinely collect field soil samples and have them analyzed for nutrient concentration. By comparing these results to known nutrient requirements, they can determine the most efficient crop nutrient management program. A soil sample from a field is usually a composite of 10 to 30 subsamples and is assumed to be a good representation of a field's fertility status.

In 1991, more than 27,000 Ohio fields were sampled for analysis by the Research-Extension Analytical Laboratory of the Ohio Agricultural Research and Development Center to determine the adequacy of soil nutrients for corn and soybean production in 1992. For this sample base, 23 percent of the fields intended for corn were deficient in phosphorus, and 66 percent were deficient in potash. Thirteen percent of the soybean fields were deficient in phosphorus, while 80 percent were deficient in potash. Of those fields with "greater than minimum" levels of both phosphorus and potassium for corn and soybean production, about 25 percent had excessive levels of phosphorus, and 4 percent had excessive levels of potassium. On average, soil test levels of phosphorus were satisfactory, but potassium levels were low. Unfortunately, about half of the tested fields had either excessive or deficient levels of phosphorus, and 75 percent had incorrect levels of potassium. Correcting nutrient levels in these fields could increase the efficiency of corn and soybean production either by reducing purchases of unnecessary fertilizers or by increasing the fertility levels where deficient, thus increasing yield and reducing the per-unit cost of production.

In recent years, some producers have attempted to increase nutrient use efficiency by sampling fields according to soil type rather than taking a "whole-field" composite sample. This permits the various soils in a field to be amended as needed rather than being treated identically. Researchers at The Ohio State University and some farmers are now using a more elaborate technique that involves sampling fields at uniform spacings in a grid pattern. Each sample is analyzed and the data used to create a map showing the distribution of each fertilizer nutrient by concentration throughout the field. These nutrient concentration maps can be computerized and used to control a fertilizer spreader as it traverses a field, controlling the amount of each nutrient applied in each area of a field.

A less sophisticated use of these maps involves using the information as a guide to general areas of a field where different application rates of various nutrients are needed. This sampling and nutrient-application procedure, sometimes called *prescription farming* or *grid nutrient management*, could be a highly efficient method of locating nutrient shortages, or "hot spots," and establishing a more uniform and appropriate level of soil nutrients throughout a field. The efficiency comes from withholding nutrient applications where levels are already sufficient, while correcting deficient areas. Nutrient applications in areas where concentrations are already too high may reduce uptake of micronutrients and reduce yield. Locating areas of excessive phosphate and potash enables producers to eliminate over-fertilization, which is environmentally prudent and cost-effective.

The grid spacing distance for this sampling technique can vary from as little as 30 feet to several hundred feet, depending on nutrient concentration variability, topography and the precision desired. For ease of use and interpretation, the grid spacing should be some multiple of the spreading width of the fertilizer applicator (30 to 60 feet).

Table 1. The Effect of Soil Sampling Grid Size on the Number of Samples per 10-Acre Unit and Cost of Soil Analysis

Grid Spacing (feet)	Samples per 10 Acres	Analysis Cost per 10 Acres ($)*
Square		
60	120	600
120	24	120
180	13	65
240	8	40
300	5	25
360	3	15
420	3	13
480	2	10
Rectangular		
60 x 120	60	300
60 x 180	40	200
60 x 240	30	150
60 x 300	24	120
60 x 360	20	100
60 x 420	17	85
60 x 480	15	75

* Assumes $5 per sample.

In fields where fertilizer spreaders have followed the same general spreading pattern for several years, a rectangular rather than square grid sampling pattern may be suitable. The shape of this rectangle may be 2 to 4 times longer than wide. This strategy could greatly reduce sampling and analysis costs. As shown in Table 1 (previous page), the smaller the sampling grid or rectangle, the greater the number of samples and expense for soil analysis.

While the average level of soil fertility for an entire field may be known, the nutrient level variation is usually unknown. Wide grid spacings reduce the number of samples and analysis cost, but may not provide adequate definition of the nutrient's concentration variation pattern to serve as an effective guide for nutrient correction. This defeats the purpose of grid sampling. On the other hand, intensive sampling and analysis are very expensive. Growers must select the optimum combination of sampling frequency and cost. Enough samples must be taken to get a clear picture of the nutrient variation without creating excessive costs that cannot be recaptured through more efficient nutrient application. How can this be done?

Although the nutrient variability of a field is not known, there is an alternative to guessing at an appropriate grid spacing. One option is to collect a series of soil samples spaced 30 to 60 feet apart in a straight line 400 feet to 500 feet long perpendicular to the fertilizer spreader's usual travel direction. Analyzing these samples and studying the results will give an indication of the field's nutrient variability and indicate an appropriate sample spacing without creating a great expense.

Likewise, a similar series of samples collected in a direction parallel to the travel of the fertilizer spreader may indicate that a rectangular sampling pattern is satisfactory. A composite soil sample for each collection point, or grid intersect, should consist of five sub-samples — one at the intersect and two samples taken on the line to each side at distances of 5 and 10 feet.

Figure 1A shows data for a field sampled every 60 feet

Fig. 1A. Soil P at 60-Foot Sampling Intervals

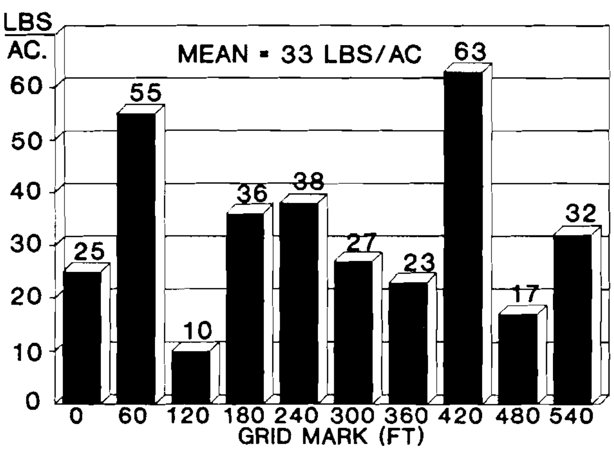


Fig. 1B. Soil P at 120-Foot Sampling Intervals

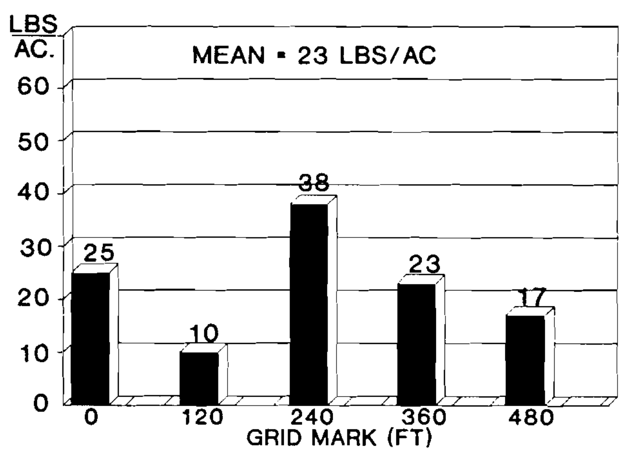


Fig. 1C. Soil P at 180-Foot Sampling Intervals

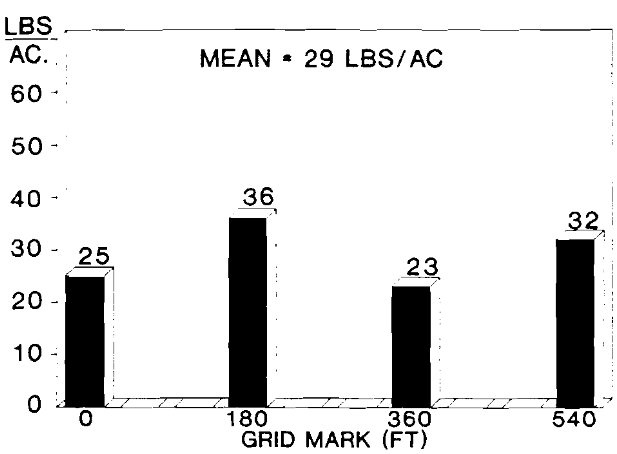


Fig. 1D. Soil P at 200-Foot Sampling Intervals

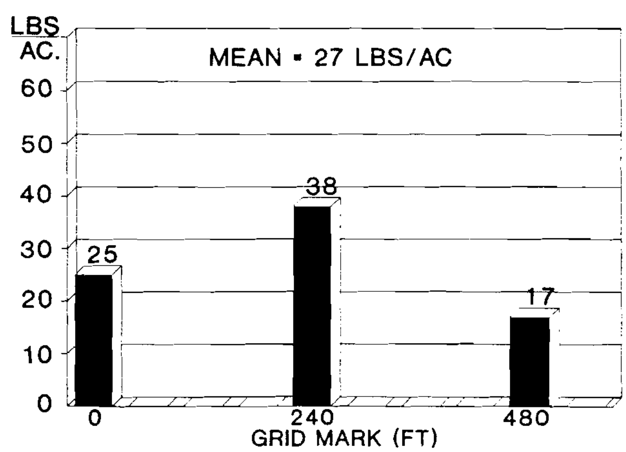


Fig. 2. Distribution of Soil P in the 144-Acre Field

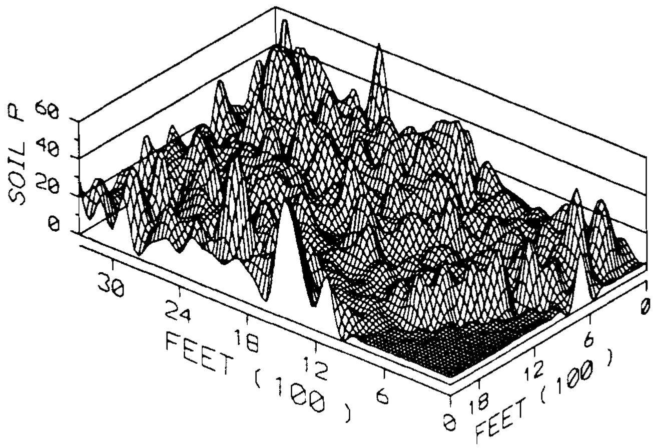
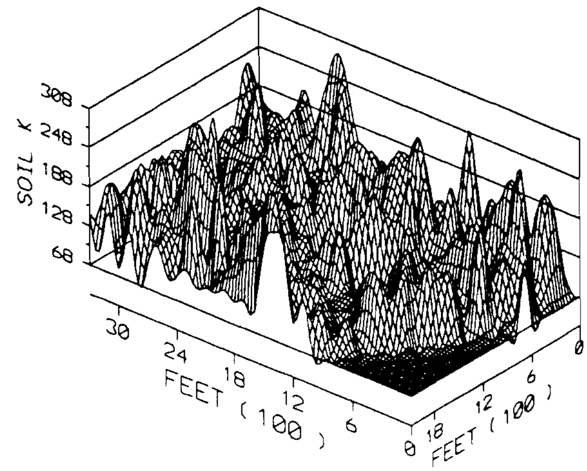


Fig. 3. Distribution of Soil K in the 144-Acre Field



in a straight line for 540 feet. In Figure 1A, every sample value (pounds of phosphorus per acre) was plotted, while in Figures 1B, 1C and 1D, every 2nd, 3rd or 4th sample value, respectively, was plotted. Depending on the distance between samples or the number of samples, the phosphorus concentration means vary from 23 to 33 pounds of phosphorus per acre. The cost of enough phosphate to change the soil test level from 23 to 33 is about $22 per acre. If only one sample from this field had been collected, the soil test value could have been as low as 10 or as high as 63, assuming those were the lowest and highest values present. This variation provides the rationale for collecting and compositing many subsamples from a field where one analysis will be used to represent an entire field.

Once the ideal grid spacing is determined and soil samples are collected and analyzed, the data for each plant nutrient can be plotted to produce a three-dimensional graph. As an example, a 144-acre field was grid-sampled every 100 feet and the samples were analyzed for pH, phosphorus, potassium and CEC. Figures 2 and 3 show the distribution of soil phosphorus and potassium levels in three-dimensional graphs, which indicate a wide variation over the field.

The variation from sample to sample can be made to appear great or small, depending on scaling factors used for plotting the vertical (concentration) scale. To illustrate that possibility, Figure 4 was made using the same data presented in Figure 3. Because one can easily misinterpret data presented in a 3-D format, management decisions should be based on 1) the actual data and 2) the realistic precision that can be expected from the application equipment. Computer plotting software makes it possible to "slice through" such charts to get an idea of the location

Fig. 4. Distribution of Soil K in the 144-Acre Field, Plotted Using a Different Scaling Factor

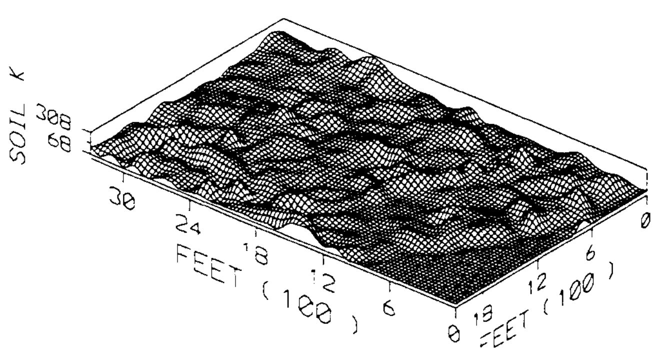
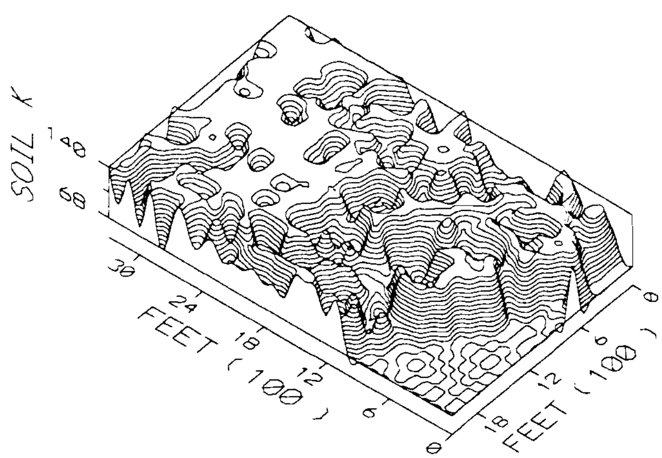


Fig. 5. Area Where Soil K Is Greater and Less Than 140 lb. K per Acre



and amount of area above or below a particular soil test value. An example of this technique is shown in Figure 5.

Figures 6A, 6B, 6C and 6D show the acreages of various levels of soil pH, phosphorus, potassium and CEC values in the 144-acre sample field. Expected crop yields for each grid point and an average yield for the field were calculated using these data. Calculations were also made to determine the yield loss due to inadequate fertility, the cost of correcting phosphate and potash deficiencies, and the expected profit from making needed additions.

To obtain maximum grain yields without fertilization in a corn-soybean rotation, the soil phosphorus level should be at least 40 pounds of available phosphorus per acre (Figure 7). The minimum soil test level for potassium should be at least 280 + 5 times the CEC value (Figure 8). Expected soybean and corn yields for the existing fertility levels were calculated (Figures 9A and 10A), as were the expected yields following nutrient corrections (Figures 9B and 10B).

The graphs assume favorable weather, use of good management practices, and no micronutrient shortages. The important question is whether it is profitable to correct the fertility deficiencies of each grid section in this sample field. The answer depends on nutrient cost, assumed value of corn and soybeans, and the cost of precision spreading. For this example, it was assumed that phosphate cost 22 cents per pound and potash cost 11 cents per pound. Previous research shows that 10 pounds of phosphate per acre are needed to increase the available soil phosphorus one unit (from 30 to 31), and about 5 pounds of potash per acre are needed to increase the soil potassium level one unit (250 to 251). This example assumed the use

Fig. 6A. Acreages of Various Ranges of Soil P Values

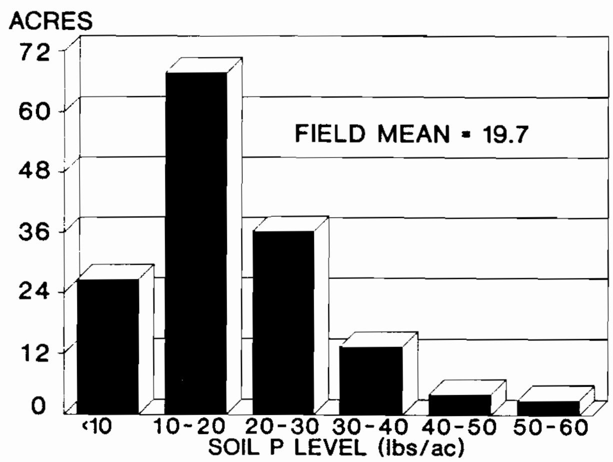


Fig. 6B. Acreages of Various Ranges of Soil K Values

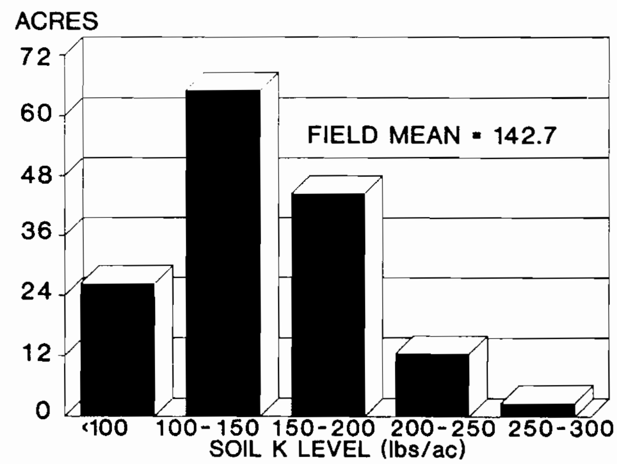


Fig. 6C. Acreages of Various Ranges of Soil pH Values

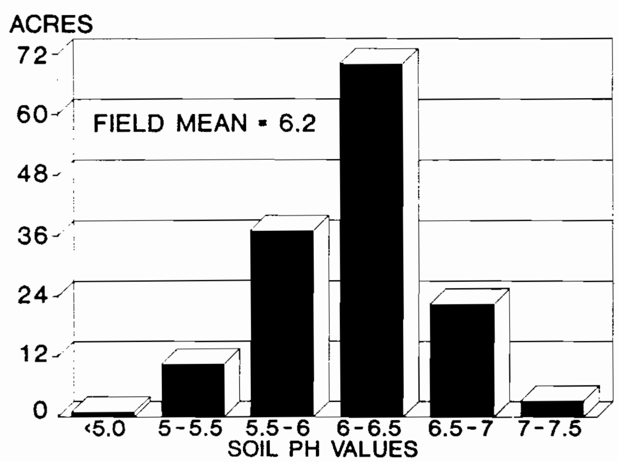


Fig. 6D. Acreages of Various Ranges of Soil CEC Values

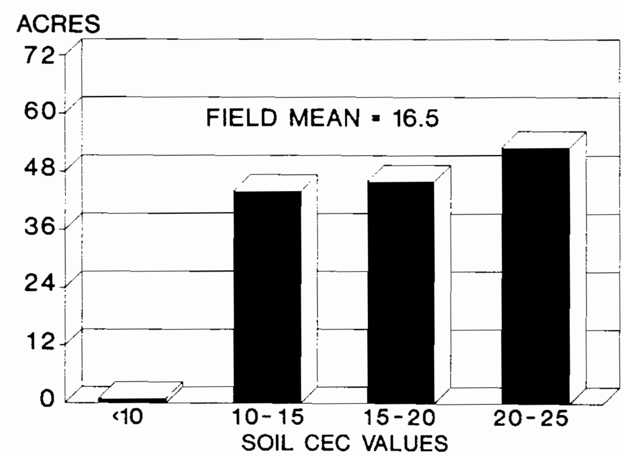


Fig. 7. Corn and Soybean Yield Response to Soil P

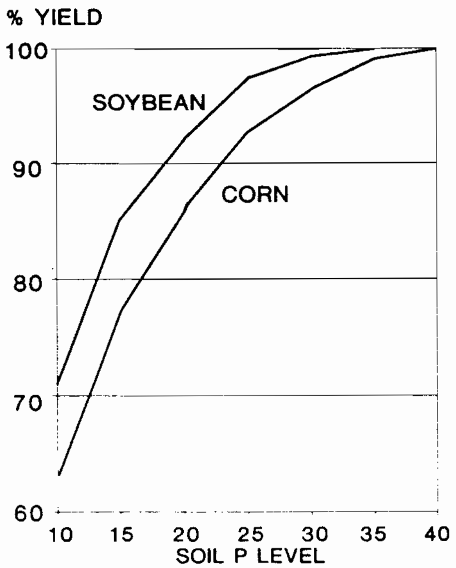
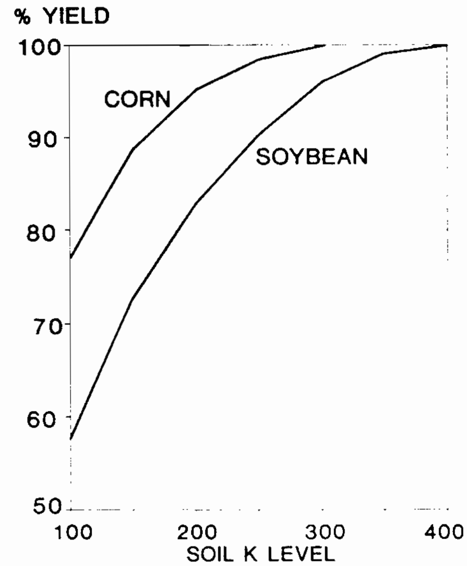


Fig. 8. Corn and Soybean Yield Response to Soil K



of a corn-soybean rotation, with corn worth $2.50 per bushel and soybeans worth $6 per bushel. The cost of collecting ($1) and analyzing ($5) the soil samples was also considered.

Figure 11 shows the acreage distribution of fertilizer cost, including sample collection and analysis, which averaged $198.13 per acre. The increase in average annual income due to correcting soil phosphorus and potassium levels in a corn-soybean rotation was $97 per acre. Therefore, the cost of soil sampling, soil analysis and nutrient application would be recovered in about two years, assuming predicted yields and no pH or micronutrient problems.

Table 2 contains an abbreviated summary of the costs and benefits of a correction program for three parts of the sample field. Area "A" consisted of 12 acres with the lowest levels of nutrients. Although nutrient cost was greatest for this area, the nutrient costs were recovered sooner than for other areas of the field because yield increases were large here. Area "B" consisted of the 12 acres with the highest nutrient concentrations, although the area was deficient in both phosphorus and potassium. Because less correction was needed in Area B, the yield increases were smaller than for Area A, and the number of crop years needed to pay for correction increased. This difference exists because the concept of "diminishing returns" applies. In general, this concept states that as the "optimum" is approached, the rate of improvement decreases and approaches zero. Farmers have observed this principle at work in recent years. As yields have increased, additional yield increases have been more difficult and

Fig. 9A. Acreages of Expected Soybean Yields Before Correction

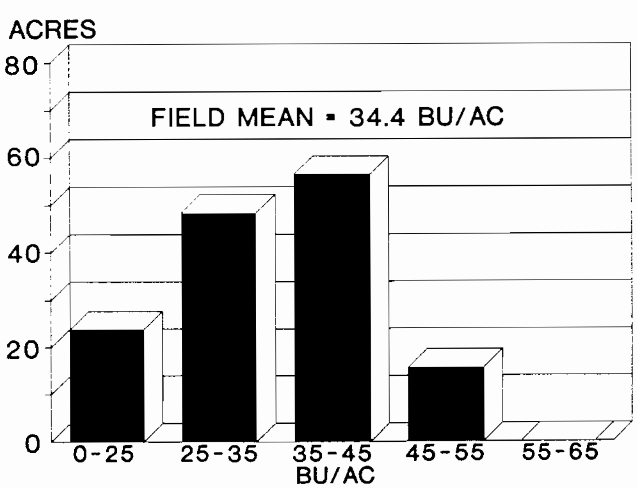


Fig. 9B. Acreages of Expected Soybean Yields After Correction

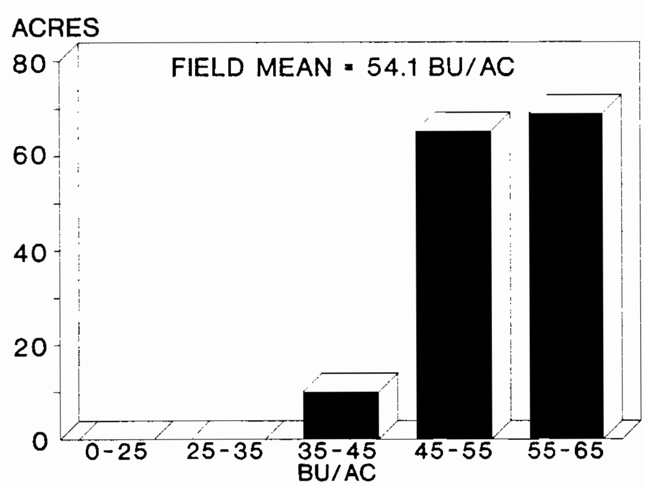


Fig. 10A. Acreages of Expected Corn Yields Before Correction

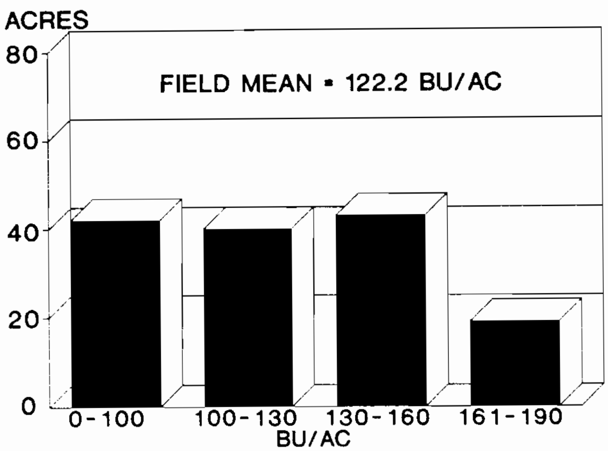
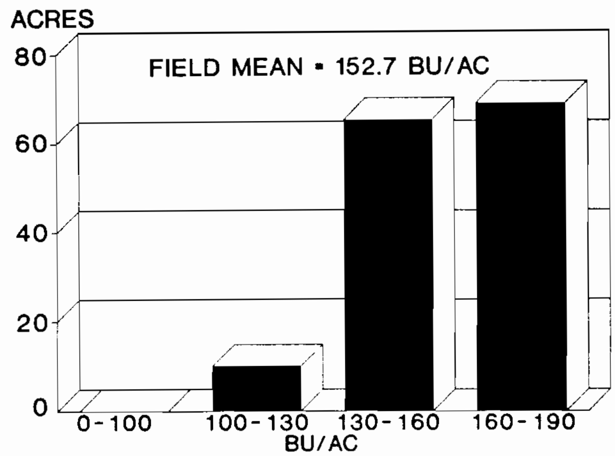


Fig. 10B. Acreages of Expected Corn Yields After Correction

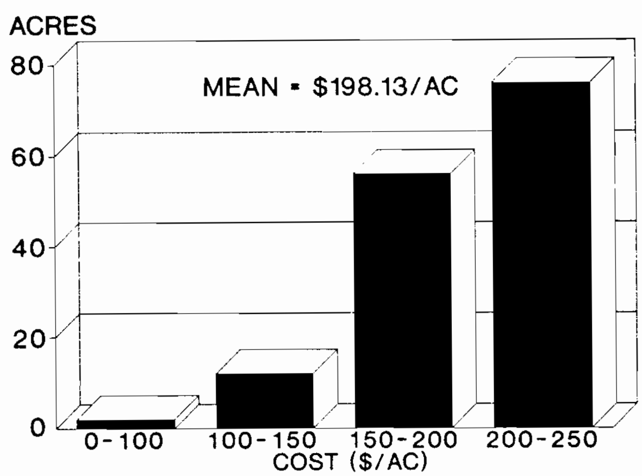


expensive to achieve. Area "C" in Table 2 represents the entire 144 acres, including Areas A and B, and shows mean values for the field.

Is a grid fertilization procedure more profitable than the conventional method of using a single composite soil test and treating the field uniformly? The original average soil test values for the sample field were as follows: soil phosphorus = 20 and soil potassium = 143. For a corn-soybean rotation with yield goals of 150-bushel-per-acre corn and 50-bushel-per-acre soybeans, we would apply 75 pounds of P_2O_5 and 200 pounds of K_2O each year. This fertilizer would cost $41 per acre per year including application and would increase the corn and soybean yields to 152 bushels per acre and 54 bushels per acre, respectively (same as the grid procedure). The value of this yield increase is about $97 per acre, leaving a profit to fertilizer application of $56 per acre. Better yet, 26 pounds of P_2O_5 and 143 pounds of K_2O would be left over to increase soil test levels. Using this approach, soil phosphorus and potassium would reach the optimum levels of 40 and 373 in about 8 years. Crop yields during the 8-year buildup with the conventional system and for the 8 years after the grid correction would be equal, assuming crop removal of phosphorus and potassium are applied annually to the grid system after initial correction. Table 3 compares costs of the two systems.

An advantage of the grid system is that each grid section of the field would be fertilized in accordance with its production potential, and no area would be excessively fertilized. The grid system has a significant up-front expense, but produces maximum yields with minimum fertilizer investment. An advantage for the conventional system is a large savings in sample collection and analysis

Fig. 11. Acreages of Fertilizer Cost, Including Sample Collection and Analysis



and no yield losses due to low fertility. The disadvantage is that excessive fertilizer will be applied in areas of higher fertility, while the lowest-fertility areas would not be corrected completely for at least 12 years. Following 12 years with the conventional system to correct the low-fertility areas, the areas initially high in phosphorus and potassium will have excessive nutrient levels: P = 64, K = 486. Thus, the conventional system of fertilizing will produce yields as good as the grid system, but excessive fertilizer will be purchased and applied, making it inefficient and environmentally undesirable. The grid fertilization program would cost $4 to $5 more per acre each year over the 8-year period following correction than the normal fertilization program. The extra cost is due primarily to extra soil testing and precision spreading.

Table 2. Nutrient Cost and Increased Income Due to Correcting Soil Phosphorus (P) and Potassium (K) Levels in Low- and High-Fertility Areas of the Field and the Entire 144-Acre Field

	Original Soil Test Levels			Desirable Soil Test Levels		Corrective Fertilizer Cost		
Sample[1]	P	K	CEC	P	K	P	K	Total[2]
	(lb/acre)			(lb/acre)		($/acre)		
A	12	79	13.6	40	348	63	148	211
B	33	234	22.2	40	391	21	86	107
C	20	143	18.5	40	373	46	126	172

	Original Yield		Post-Correction Yield		Increased Income Due to Correction[3]		
Sample[1]	Soy	Corn	Soy	Corn	Soy	Corn	Avg.
	(bu/ac)		(bu/ac)		($/ac)		
A	21	82	47	106	156	60	108
B	47	159	58	179	64	50	58
C	34	122	54	152	119	75	97

[1] "A" = 12.0 acres of lowest fertility; "B" = 12.0 acres of highest fertility; "C" = means for 144 acres.
[2] Does not include sample collection and analysis ($26.13 per acre).
[3] Soybeans = $6 per bushel; Corn = $2.50 per bushel.

Table 3. Fertilization Cost Comparisons of Grid and Conventional Methods of Soil Sampling

	Cost per Acre		Annual Cost for 8 Years
Grid Method			
Soil Sampling and Testing (100' x 100' grid)	$26.13		$3.26
Corrective Fertilizer	$172.00		$21.50
Initial Precision Spreading	$12.50		$1.56
Annual Crop Removal Fertilizer			$16.50
Annual Fertilizer Application			$2.50
		Total	$45.32
Conventional Method			
Annual plus Buildup P and K			$38.50
Annual Fertilizer Application			$2.50
		Total	$41.00

Summary

In summary, grid sampling and fertilization may be less profitable for fields with uniformly low levels of nutrients. Where nutrient concentrations in the entire field are already above the corn and soybean yield response levels (P = 40, K = 325), adjusting the lower nutrient areas upward for uniformity is an expense without compensation. In addition to the obvious environmental consequences, the availability of some micronutrients can be decreased and yields reduced by excessive soil levels of phosphorus and potassium.

Preliminary sampling should be used to indicate nutrient variation and acceptable grid size. Grids should be as large as possible to reduce cost, but small enough to provide a good picture of nutrient variation. Grid spacing should be some multiple of the spreading width of the fertilizer applicator and may be extended parallel to the spreading direction to reduce sample collection and analysis cost if analysis of preliminary samples indicates relatively consistent nutrient levels.

While a grid sampling program is somewhat laborious and sample analysis can be expensive, the fertility level throughout the field can be adjusted to an optimum level so that, in future years, conventional sampling and uniform application would be satisfactory for good yields and fertilizer efficiency. Uniform application will result in the gradual migration to uneven nutrient concentrations, which will require correction every 15 to 25 years. The current single composite sample and uniform treatment method is satisfactory for near-maximum yields, but leaves areas of over- and under-fertilization, resulting in inefficient use of fertilizer dollars and the potential for environmental degradation.

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